U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB80-124126

# Automotive Exhaust and Mouse Activity Relationships between Pollutant Concentrations and Decreases in Wheel Running

(U.S.) Health Effects Research Lab, Research Triangle Park, NC

1979

MS-79-046

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| | |
|---|---|
| 1. REPORT NO. EPA-600/J-79-043 | 2. JOURNAL ARTICLE |
| 3. | PB80-124126 |
| 4. TITLE AND SUBTITLE: AUTOMOTIVE EXHAUST AND MOUSE ACTIVITY: RELATIONSHIPS BETWEEN POLLUTANT CONCENTRATIONS AND DECREASES IN WHEEL RUNNING | 5. REPORT DATE |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S): Michael I. Gage | 8. PERFORMING ORGANIZATION REPORT NO. |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS: Experimental Biology Division, Health Effects Research Laboratory, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711 | 10. PROGRAM ELEMENT NO. 1EA615 |
| | 11. CONTRACT/GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS: Health Effects Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711 RTP, NC | 13. TYPE OF REPORT AND PERIOD COVERED |
| | 14. SPONSORING AGENCY CODE EPA 600/11 |

15. SUPPLEMENTARY NOTES

Published in: Arch. Environ. Health 34(3):164-168, 1979

16. ABSTRACT

Groups of male and female mice inhaled either clean air, 100 ppm carbon monoxide, or light-irradiated and nonirradiated automotive exhaust containing nominally 25, 50, 75, or 100 ppm carbon monoxide in three tests with exposure lasting from 4 to 7 days. Exhaust from a factory or lean-tuned engine in the first and third tests reversibly suppressed activity wheel running during exposure in mice of both sexes by as much as 78.3 and 83.1% respectively. Light-irradiated exhaust suppressed running more than nonirradiated exhaust. For the second test, when the engine was tuned to be low in pollutants other than carbon monoxide, exhaust did not suppress running. Exposure to carbon monoxide alone only slightly decreased running in male mice, but increased running in female mice.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Motor Vehicle Engines<br>Exhaust Emissions | | 06C |

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

| | | |
|---|---|---|
| 18. DISTRIBUTION STATEMENT: RELEASE TO PUBLIC | 19. SECURITY CLASS (This Report): UNCLASSIFIED | 21. NO. OF PAGES: 8 |
| | 20. SECURITY CLASS (This page): UNCLASSIFIED | 22. PRICE: A02-A01 |

ARCHIVES OF ENVIRONMENTAL HEALTH,
34(3):164-168, May/June 1979.

EPA-600/J-79-043
JOURNAL ARTICLE

# Automotive Exhaust and Mouse Activity: Relationships between Pollutant Concentrations and Decreases in Wheel Running

MICHAEL I. GAGE, Ph.D.
U.S. Environmental Protection Agency
Cincinnati, Ohio

## ABSTRACT

Groups of male and female mice inhaled either clean air, 100 ppm carbon monoxide, or light-irradiated and nonirradiated automotive exhaust containing nominally 25, 50, 75, or 100 ppm carbon monoxide in three tests with exposure lasting from 4 to 7 days. Exhaust from a factory or lean-tuned engine in the first and third tests reversibly suppressed activity wheel running during exposure in mice of both sexes by as much as 78.3 and 83.1%, respectively. Light-irradiated exhaust suppressed running more than nonirradiated exhaust. For the second test, when the engine was tuned to be low in pollutants other than carbon monoxide, exhaust did not suppress running. Exposure to carbon monoxide alone only slightly decreased running in male mice, but increased running in female mice.

AUTOMOTIVE EXHAUST, as well as some of its major components and photochemical reaction products, have been implicated in the production of behavioral changes in laboratory animals. Spontaneous activity of mice has been reduced by exposure to laboratory-produced automotive exhaust emissions.[1,2] The ambient air of Riverside, California, which contains elevated levels of automotive exhaust similar to levels found in many urban centers,[3,4] synthetically produced smog,[5] or peroxyacetyl nitrate, a constituent of photochemical air pollution[6] have also been shown to decrease animal activity. A lower number of conditioned avoidance responses were seen in exposed rats than in control rats at the end of a 2-yr exposure to automotive exhaust gas.[7] Response rates of rats on schedules of reinforcement were reduced by as little as 100 ppm of carbon monoxide (CO).[8]

The research reported here was undertaken to see if the changes in behavior of animals exposed to automotive exhaust would be differentially sensitive to several levels of exhaust in the atmosphere. This research differed from prior studies in the use of recent model engines tuned in several ways to alter pollutant emission levels, and in the simultaneous exposure of different groups of subjects to multiple levels of exhaust. Activity wheel running of mice was chosen as the behavioral measure because of the prior successful use of this method for the detection of effects due to exposure to automotive exhaust,[1,2] and because this method eliminates the need for special training of the animals.

## Materials and Methods

### *Exhaust Atmosphere Generation*

A 1972 Chevrolet, V-8 engine, with a piston displacement of 5,735 $cm^3$ (350 $in^3$), was used to produce the exhaust. To simulate the exhaust resulting from urban driving conditions, the engine was operated automatically on a repeated 137-sec, seven-step cycle of idle, several

acceleration and cruise steps and deceleration.[9,10] The fuel used throughout the study was a standard reference fuel, an unleaded, 91-octane test fuel, intermediate grade, called "Indoline-Clear," containing virtually no additives. Engine exhaust, which was diluted by mixing with clean filtered air, was either routed directly into the exposure chambers, or through 19 $m^3$ (683 $ft^3$) steel and plastic irradiation chambers prior to passage into the exposure chambers.[11] Irradiation by daylight and ultraviolet fluorescent lamps for a period of about 60 min simulated the effects of sunlight and induced the photochemical reactions that would occur in the natural environment.

This study consisted of three separate exposure tests which differed mainly in the concentration of pollutants in the automotive exhaust. Pollutant concentration was varied by retuning the engine and altering the dilution ratios of the exhaust with clean air so the CO levels remained the same in the three exposure tests. Because exhaust emissions are mixtures of many chemicals, the diluted exhaust concentration was expressed in terms of desired CO levels in the total volume of exhaust and air mixture. These CO levels were chosen to approximate conditions sometimes encountered in peak urban traffic situations.

In the first exposure test, *A*, the carburetor adjustment was kept at the factory setting ("lean"). Engine exhaust was diluted to contain approximately 25, 50, 75, or 100 ppm CO. In the second exposure test, *B*, the engine was tuned to obtain maximum manifold vacuum at idle (optimal performance). Engine exhaust levels contained either 50, 75, or 100 ppm CO. In the third exposure test, *C*, the engine was retuned to factory specifications to match the conditions of exposure *A*. Exhaust levels contained either 50, 75, or 100 ppm CO.

The major components characterized in the exhaust emissions were measured in the inhalation exposure chambers during the course of each exposure test. The analytic methods used for measuring the exhaust pollutants have been reported elsewhere.[10] Carbon monoxide was measured by nondispersive infrared spectroscopy, hydrocarbons were measured by flame ionization spectroscopy, and the nitrogen oxides were measured by colorimetry with the Saltzman reagent.

For each exposure test, new 10- to 12-wk-old CD-1, COBS albino mice (obtained from Charles River Mouse Farms, Inc.) were divided into eight or ten groups of three males and three females. Male mice weighed between 30 and 44 g while female mice weighed between 22 and 34 g at the start of the exposures. The mice were placed in individual 14.5-cm (5-¾-in) diameter stainless steel activity wheels which were attached to 14.5 × 7 × 4 cm compartments allowing continuous access to food and water. A microswitch caused a counter to increment once with each revolution of the wheel. Mouse activity was measured by revolution counts recorded once each day. The groups of six mice in activity wheels were placed on the upper shelves of 1.2 $m^3$ (44 $ft^3$) inhalation exposure chambers.[12] Air flow rate in these chambers was 0.31 $m^3$/min (11 $ft^3$/min).

Each of the three exposure tests was divided into three contiguous periods, each lasting several days. During the first period all mice lived in an atmosphere of clean, chemically, biologically, and radiologically filtered air. During the second period, different groups of male and female mice were exposed to either clean air; filtered air containing 100 ppm CO; or one of the several concentrations of irradiated or nonirradiated engine exhaust which was diluted with filtered air. During the third period all mice again lived in an atmosphere of clean, filtered air. Exposure test A consisted of 9.5 days of continuous activity monitoring comprised of a 2.5-day pre-emission period, followed by a 4-day emission exposure period, and a 3-day post-emission period. Exposure test B consisted of 14 days of continuous activity monitoring divided into a 5-day pre-emission period, a 7-day emission exposure period, and a 2-day post-emission period. Exposure test C lasted 16 days, and was divided into a 7-day pre-emission period, a 7-day emission exposure period, and a 2-day post-emission period.

## Results

Measured values for the major chemical and physical constituents of the atmosphere during the emission periods of the exposures are presented in Table 1. The ranges of temperature and humidity were similar during each exposure. In general, and with the same dilution ratio, CO, total hydrocarbons, and nitric oxide (NO) appeared in somewhat lower concentrations in the irradiated exhaust than in the nonirradiated exhaust. At each dilution ratio, nitrogen dioxide ($NO_2$) was found in greater concentration in the irradiated exhaust than in the nonirradiated exhaust. Exhaust from the optimally tuned engine in exposure B contained concentrations of hydrocarbons, NO and $NO_2$, that were below concentrations found during exposures A and C.

The mean and standard error of daily wheel revolutions during exposure A, the exposure to factory-tuned engine emissions or control atmospheres, are shown in Figure 1 (upper-left panel). Analysis of variance[13] indicated a significant effect due to atmosphere ($F = 4.4$, df = 9/40, $P < .001$), sex ($F = 17.7$, df = 1/40, $P < .001$), and atmosphere by sex interaction ($F = 2.3$, df = 9/40, $P < .05$). Duncan's multiple range test was performed to detect significant differences among the mean daily counts at the .05 level for each group of mice. Females exposed only to CO had counts significantly higher than those of any other group. Mice exposed to clean air had significantly higher mean daily counts than mice exposed to the two highest levels of irradiated exhaust.

In exposure A, the mean of daily counts for all mice breathing clean air was 11,912, while the mean for all mice inhaling the highest concentration of irradiated exhaust was 2,590 counts. Mice exposed to irradiated exhaust had lower activity counts than mice exposed to nonirradiated exhaust, except for males exposed to exhaust containing 25 ppm CO. However, these differences were usually small. With one exception, males made fewer daily revolutions than the females of any exposure group.

Figure 1 (upper-right panel) shows the mean revolutions per day of the combined counts for both male and female

Table 1.—Pollutant Levels in Animal Exposure Chambers

| Atmosphere | Nominal CO Concentration (ppm) | Exposure A Carburetor Set Lean | | | | Exposure B Carburetor Set for Optimal Performance | | | | Exposure C Carburetor Reset Lean | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CO (ppm ± SD) | Hydrocarbons (ppm ± SD) | NO (ppm ± SD) | $NO_2$ (ppm ± SD) | CO (ppm ± SD) | Hydrocarbons (ppm) | NO (ppm ± range) | $NO_2$ (ppm ± range) | CO (ppm ± SD) | Hydrocarbons (ppm ± SD) | NO (ppm ± SD) | $NO_2$ (ppm ± SD) |
| Nonirradiated exhaust | 25 | 36 ± 3.8 | 37 ± 4.8 | 3.4 ± 0.7 | 0.7 ± 0.1 | | | | | | | | |
| | 50 | 63 ± 4.1 | 64 ± 5.3 | 16.2 ± 1.6 | 1.7 ± 0.1 | 56.3 ± 5.5 | 3.1 | 3.3 ± 1.1 | 0.1 ± 0.1 | 59.7 | 71.0 | 10.5 | 1.7 |
| | 75 | 83 ± 7.1 | 83 ± 7.4 | 21.1 ± 1.8 | 2.8 ± 0.2 | 79.9 ± 5.2 | 4.3 | 4.2 ± 1.6 | 0.2 ± 0.2 | 74.0 | 87.6 | 13.3 | 2.2 |
| | 100 | 93 ± 6.6 | 98 ± 9.4 | 23.7 ± 1.4 | 3.6 ± 0.2 | 98.5 ± 4.7 | 4.8 | 5.8 ± 2.3 | 0.3 ± 0.3 | 92.4 | 108.9 | 17.4 | 3.2 |
| Irradiated exhaust | 25 | 33 ± 4.3 | 34 ± 6.7 | 6.4 ± 0.4 | 2.5 ± 0.5 | | | | | | | | |
| | 50 | 54 ± 7.2 | 53 ± 8.6 | 8.7 ± 1.3 | 4.8 ± 0.6 | 49.4 ± 4.2 | 2.6 | 2.2 ± 1.0 | 0.6 ± 0.6 | 50.5 ± 7.8 | 54.8 ± 35.6 | 5.7 ± 1.3 | 5.9 ± 0.7 |
| | 75 | 70 ± 9.5 | 67 ± 9.7 | 12.0 ± 2.1 | 6.8 ± 0.8 | 75.4 ± 4.7 | 4.2 | 3.6 ± 2.1 | 1.8 ± 1.3 | 68.0 ± 4.5 | 74.2 ± 14.4 | 8.1 ± 1.5 | 6.9 ± 0.6 |
| | 100 | 96 ± 11.3 | 102 ± 14.1 | 18.9 ± 1.8 | 8.6 ± 1.0 | 101.8 ± 6.2 | 4.8 | 5.2 ± 1.7 | 1.5 ± 1.3 | 92.2 ± 6.4 | 96.9 ± 15.6 | 11.8 ± 1.6 | 8.7 ± 0.8 |

mice exposed at the highest level of nonirradiated and irradiated exhaust and clean air, for each of the days prior to, during, and after the emissions exposure period of exposure A. Mice exposed to exhaust atmospheres, decreased their running within the first day of emissions exposure, and continued the decreases until this exposure was terminated. Within one day after breathing clean air again, daily revolution counts either returned to, or exceeded, the pre-exposure level.

Results of the exposure to the emission of an optimally tuned engine in exposure B are presented in Figure 1 (lower-left panel). There were no significant differences in daily revolutions among the various groups in exposure B ($F = 0.95$, df = 7/32, $P = 0.48$), but there was a significant difference between the sexes ($F = 16.1$, df = 1/32, $P < .001$).[13] For most of the groups the males made fewer revolutions than the females.

Mean daily revolutions of mice exposed to emissions of the engine retuned to factory specifications in exposure C are presented as a function of exposure atmosphere in Figure 1 (lower-right panel). An analysis of variance showed significant effects due to atmosphere ($F = 28.0$; df = 7/32, $P < .001$), sex ($F = 35.1$, df = 1/32, $P < .001$) and atmosphere by sex interaction ($F = 7.8$, df = 7/32, $P < .001$).[13] Once again female mice exposed only to CO had a mean daily count significantly higher than that of any other group and mice exposed to clean air had daily revolution counts that were significantly higher than those of the same sex exposed to all levels of irradiated or nonirradiated exhaust. In exposure C, mice inhaling clean air had a mean daily revolution count of 13,418, while those inhaling the highest concentration of irradiated exhaust had only 2,268 counts per day. Males had fewer revolutions than females in each treatment group, and exposure to irradiated exhaust produced lower counts than exposure to nonirradiated exhaust with a single exception. There were no significant weight changes over the testing period due to exposure to any atmosphere.

Exhaust emissions suppressed the wheel running, since revolution counts decreased upon initiation of exposure, stayed low throughout exposure, and returned to, or exceeded their pre-exposure levels after termination of exposure. This was observed even though no attempt was made to preselect mice for high pre-exposure activity or low variability of wheel running as had been done in some earlier studies reporting changes in behavior consequent to automotive exhaust pollution exposure.[3,4,6]

That behavioral suppression was not a consequence of the CO in the atmosphere was shown in several ways. In exposures A and C, female mice exposed to 100 ppm CO alone showed an increase in daily revolution counts when compared to female mice exposed to clean air. Male mice exposed to CO alone decreased wheel running, but the counts were not significantly lower than counts of male mice exposed to clean air. In the exposure B, when the exhaust at all dilutions was composed primarily of CO, there were no significant differences among the treatment groups. These effects of CO exposure were quite different from the effects of exposure to exhaust containing similar concentrations of CO, and also containing high concentrations of other pollutants, confirming earlier findings.[2]

Exhaust levels were comparable in CO concentrations to those used by Hueter,[2] but the concentrations of NO, $NO_2$ and total hydrocarbons were higher in the present study. It is unlikely that wheel running suppression was due to temperature differences among the chambers since the mean temperatures varied only about 3°C, and these differences were not related to exhaust concentration.

Exposure to photochemical products of automotive exhaust generally produced greater mean activity suppression than exposure to nonirradiated exhaust. This occurred even though, in general, at any given dilution ratio, the concentrations of all major measured chemical constituents, except $NO_2$ were higher in the nonirradiated than in the irradiated exhaust. Results of this experiment support findings by Stupfel et al.[7] who showed behavior changes in rats exposed to exhaust containing 20 ppm $NO_2$. Cursory examination of the relationship between revolution counts and measured chemical constituents, suggested that activity count suppression may not have been simply a function of concentration of any single measured substance. More likely, activity suppression was related to the effect of unique combinations of pollutants present in the exposure chambers.

Automotive exhaust suppressed the wheel running activity of mice in direct relation to the concentration of pollutants other than the carbon monoxide in the exhaust. This response provides a bioassay for evaluating the physiological effects even during a relatively short exposure to automobile exhaust. The fact that a measure of behavior, which did not require training, was a toxicological indicator is important because it provides an approach to rapidly acquire data about the effects of some environmental pollutants on certain sensitive aspects of behavior.

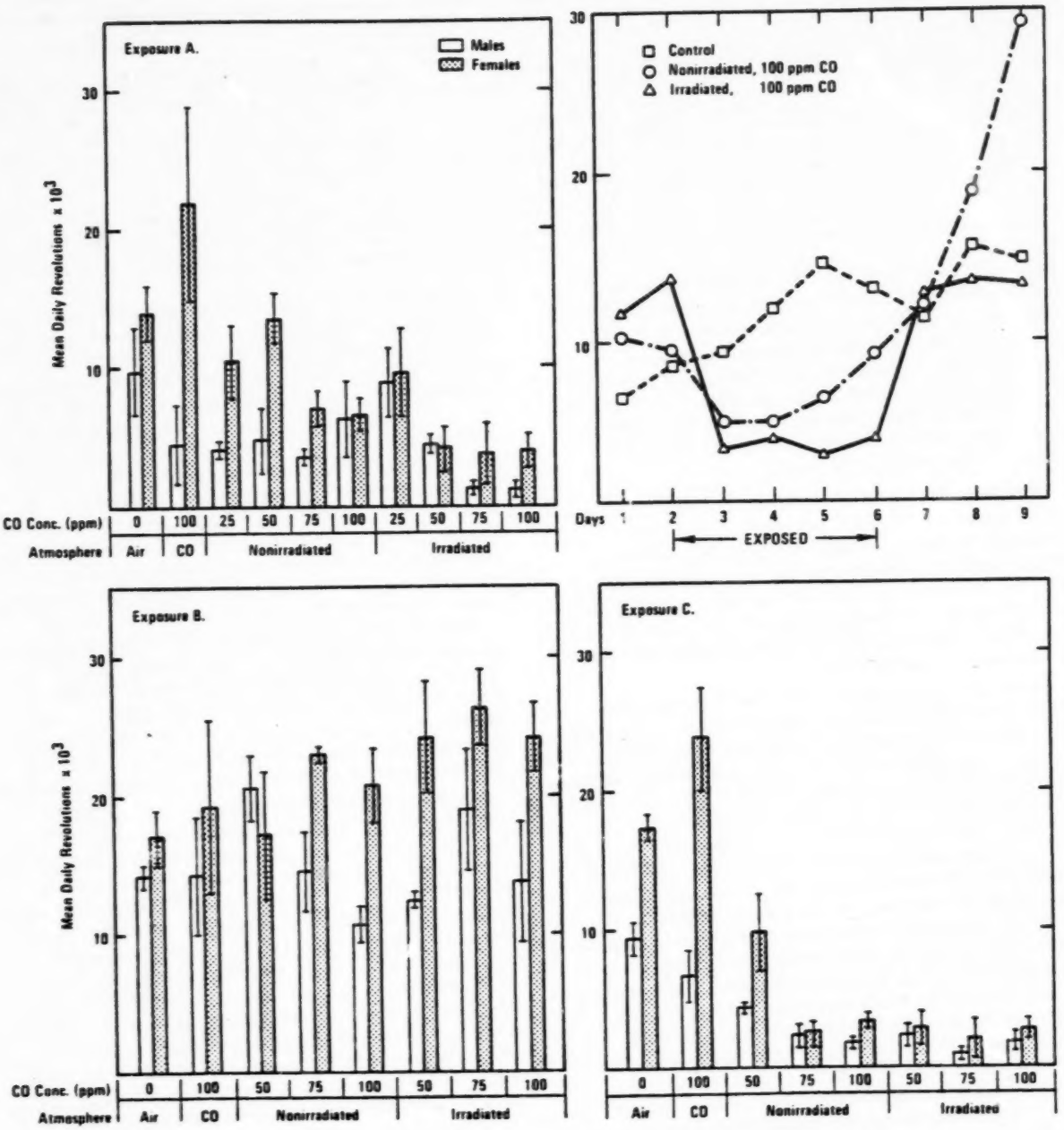


Fig. 1. Mean daily activity of mouse groups during emissions exposure periods of the three exposure tests. Exhaust level is described by nominal CO concentration. During exposures A and C engine was tuned to factory specifications. During B, engine was tuned for maximum manifold vacuum at idle. Upper right panel shows activity over the course of exposure A for both male and female mice exposed to concentrations indicated.

* * * * * * * * * * *

The author thanks, Arnold L. Cohen, Deborah Long, and Julius Williams for help in collecting behavioral data; Myron Malanchuk, Gilbert Contner, and Robert Slater for providing aerometry data; You-Yen Yang for statistical analysis of the data; Robert Hinners, Joseph Burkart, and Gerald Radigan for controlling the engines; and Jerry F. Stara, Kirby Campbell, Sidney Beck, Larry L. Hall, and Daniel F. Cahill for suggestions and critical review of the manuscript.

Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

Submitted for publication August 22, 1977; accepted for publication November 28, 1977.

Current address of author: U.S. Environmental Protection Agency, HERL, MD-74, Research Triangle Park, North Carolina 27711.

* * * * * * * * * *

## REFERENCES


1. Murphy, S. D. 1964. A review of effects on animals of exposure to auto exhaust and some of its components. *J Air Pollut Control Assoc* 14: 303-08.
2. Hueter, F. G.; Contner, G. L.; Bush, K. A.; and Hinners, R. G. 1966. Biological effects of atmospheres contaminated by auto exhaust. *Arch Environ Health* 12: 553-60.
3. Emik, L. O., and Plata, R. L. 1969. Depression of running activity in mice by exposure to polluted air. *Arch Environ Health* 18: 574-79.
4. Emik, L. O.; Plata, R. L.; Campbell, K. I.; and Clarke, G. L. 1971. Biological effects of urban air pollution. *Arch Environ Health* 23: 335-42.
5. Boche, R. D., and Quilligan, J. J. Jr. 1960. Effect of synthetic smog on spontaneous activity of mice. *Science* 131: 1733-34.
6. Campbell, K. I.; Emik, L. O.; Clarke, G. L.; and Plata, R. L. 1970. Inhalation toxicity of peroxyacetyl nitrate. *Arch Environ Health* 20: 22-27.
7. Stupfel, M.; Magnier, M.; Romary, F.; Tran, M. H.; and Moutet, J. P. 1973. Lifelong exposure of SPF rats to automotive exhaust gas. *Arch Environ Health* 26: 264-69.
8. Beard, R. R., and Wertheim, G. A. 1967. Behavioral impairment associated with small doses of carbon monoxide. *Amer J Public Health* 57: 2012-22.
9. Moore, W.; Hysell, D.; Miller, R.; Malanchuk, M.; Hinners, R.; Yang, Y.; and Stara, J. F. 1975. Exposure of laboratory animals to atmospheric manganese from automotive emissions. *Environ Res* 9: 274-84.
10. Hysell, D. K.; Moore, W.; Hinners, R.; Malanchuk, M.; Miller, R.; and Stara, J. F. 1975. Inhalation toxicology of automotive emissions as affected by an oxidation exhaust catalyst. *Environ Health Perspect* 10: 57-62.
11. Hinners, R. G. 1963. Laboratory produced automobile exhaust facility. *Biomed Sci Instrum* 1: 53-58.
12. Hinners, R. G.; Burkhart, J. K.; and Contner, G. L. 1966. Animal inhalation exposure chambers in air pollution studies. *Arch Environ Health* 13: 609-15.
13. Snee, R. D. 1972. On the analysis of response curve data. *Technometrics* 14: 47-61.


# Intake of Magnesium and Toxicity of Lead: An Experimental Model

NARAYANI P. SINGH
Institute of Environmental Medicine
New York University Medical Center
New York, NY

INDERJIT S. THIND, M.D.
Preventive Medicine and Community Health
LEONARD F. VITALE, M.D.
METODI PAWLOW, M.S.
Department of Pediatrics
New Jersey Medical School
Newark, NJ

## ABSTRACT

Groups of ten male Wistar rats were fed 100 mg lead/kg body wt · day, or 100 mg lead plus 250 mg Mg · kg body wt · day mixed in the powdered diet as chlorides. Blood and urine were monitored for lead-related enzymes and lead concentrations. Compared to the lead-treated, blood lead and urinary aminolevulinic acid were much lower and blood aminolevulinic acid dehydratase and urinary lead were higher at 30, 45, and 62 days in the lead-magnesium–treated animals. At 45 and 62 days, blood lead was higher in the lead-magnesium group even though the urinary excretion of lead was significantly higher ($P < .01$). At 62 days, the lead feeding was discontinued to both groups, but magnesium administration was continued. Both groups of rats were then monitored for urinary excretion of lead and this was significantly higher ($P < .01$) in the rats fed magnesium suggesting that magnesium intake helped mobilize lead from bone, thus increasing the blood lead level and subsequent urine excretion. Enzyme levels approached normal values at 106 days only in the lead-magnesium group, thereby indicating low levels of lead toxicity. Lead levels of bones in rats of the lead-magnesium group, when sacrificed at 106 days, were significantly lower ($P < .01$) than among those given lead alone, another indication that magnesium helped mobilize lead from bone. The results, therefore, clearly show that feeding magnesium leads to lower retention and increased excretion of lead under the experimental conditions outlined.

archives of
# Environmental Health

MAY/JUNE 1979 Volume 34 Number 3

| | | |
|---|---|---|
| Effects of Asbestos and Beryllium on Release of Alveolar Macrophage Enzymes | *K.-Y Kang, D. Bice R. D'Amato, M. Ziskind J. Salvaggio* | 133 |
| Introduction of Iron Transport by a Potent Inducer of Aryl Hydrocarbon Hydroxylase, 2, 3, 7, 8-Tetrachlorodibenzo-*p*-dioxin | *J. Manis G. Kim* | 141 |
| An Investigation of Elevated Blood Lead Levels in Detroit Children | *G. Ter Haar L. Chadzynski* | 145 |
| The Respiratory Disease Questionnaire: Use of a Self-Administered Version | *C. Mittman, T. Barbela Doris McCaw, Eugene Pedersen* | 151 |
| The Effect of Carbon Monoxide upon Erythrocyte δ-Aminolevulinicacid Dehydratase Activity | *M. Moore P. Meredith* | 158 |
| Lack of Ozone Effects on Oxygen Hemoglobin Affinity | *B. Ross, M. Hlastala R. Frank* | 161 |
| Automotive Exhaust and Mouse Activity: Relationships between Pollutant Concentrations and Decreases in Wheel Running | *M. Gage* | 164 |
| Intake of Magnesium and Toxicity of Lead: An Experimental Model | *N. Singh, I. Thind L. Vitale, M. Pawlow* | 168 |
| Subacute Cadmium Intoxication in Jewelry Workers: An Evaluation of Diagnostic Procedures | *E. Baker, W. Peterson J. Holtz, C. Coleman P. Landrigan* | 173 |
| Pulmonary Retention of Neutron-Activated Coal Dust | *P. Morrow, F. Gibb H. Beiter, R. Kilpper* | 178 |
| Carbon Monoxide and Ventricular Fibrillation Threshold in Normal Dogs | *W. Aronow E. Stemmer, S. Zweig* | 184 |

*4000 Albemarle Street, N. W., Suite 504*
*Washington, D.C. 20016*
Return Postage Guaranteed

ISSN 0003-9896